

WHAT IS CLAIMED IS:

1. A semiconductor device having a multiple layered ridge, said ridge including:

a first semiconductor layer forming the bottom part of said ridge, said first semiconductor layer having a
5 first etching speed in a first etchant;

a second semiconductor layer disposed above said first semiconductor layer, said second semiconductor layer having a second etching speed in the first etchant;
and

10 a third semiconductor layer disposed above said second semiconductor layer and forming the top part of said ridge, said third semiconductor layer having a third etching speed in the first etchant,

wherein the second etching speed is higher than the
15 first etching speed and slower than the third etching speed.

2. The semiconductor device according to claim 1, wherein said second semiconductor layer has a bottom surface located near the first semiconductor layer and top surface located near the third semiconductor layer,
5 and wherein the second etching speed is variable and increases monotonically from the layer's bottom surface to the layer's top surface.

3. The semiconductor device according to claim 2, wherein the second etching speed increases continuously from the bottom surface of said second semiconductor layer to the top surface of said second semiconductor
5 layer.

4. The semiconductor device according to claim 1,
wherein said second semiconductor layer has a bottom
surface located near the first semiconductor layer and
top surface located near the third semiconductor layer,
5 and wherein the second etching speed is variable and it
increases in one or more steps from the layer's bottom
surface to the layer's top surface.

5. The semiconductor device according to claim 2,
wherein the second semiconductor layer comprises two or
more atomic elements, and wherein the stoichiometric
ratio of the atomic elements of said second semiconductor
5 layer is changed to thereby make the second etching speed
variable.

6. The semiconductor device according to claim 1,
wherein said first semiconductor layer comprises a
composition of $\text{Al}_{x_1}\text{Ga}_{1-x_1}\text{As}$ where the stoichiometric
parameter x_1 is substantially constant, wherein said
5 third semiconductor layer comprises a composition of
 GaAs , and wherein said second semiconductor layer
comprises a composition of $\text{Al}_{x_2}\text{Ga}_{1-x_2}\text{As}$ where the
stoichiometric parameter x_2 is a variable.

7. The semiconductor device according to claim 6,
wherein the stoichiometric parameter x_1 for the first
semiconductor layer is in a range of 0.2 to 0.5.

8. The semiconductor device according to claim 1
further comprising an electrode layer disposed above said
third semiconductor layer and covering at least a side of
said ridge portion in the longitudinal direction, wherein

5 the thickness of said electrode layer is equal to or more
than 100 nm.

9. The semiconductor device according to claim 1 wherein said second semiconductor layer has a thickness in a range of 5 nm to 1000 nm.

10. The semiconductor device according to claim 1 wherein said second semiconductor layer has a thickness in a range of 25 nm to 100 nm.

11. The semiconductor device according to claim 1 wherein said second semiconductor layer has a thickness in a range of 25 nm to 35 nm.

12. The semiconductor device according to claim 11 wherein the thickness of said first semiconductor layer is greater than the thickness of said second semiconductor layer, and wherein the thickness of the third semiconductor layer is greater than the thickness of the second semiconductor layer.

~~13.~~ A method of manufacturing a semiconductor device having a multiple layered ridge, the method comprising the steps of:

forming a first semiconductor layer as a bottom
5 part of the ridge, said first semiconductor layer being
etched at a first etching speed by a first etchant;

forming a second semiconductor layer above said first semiconductor layer, said second semiconductor layer being etched at a second etching speed by the first etchant; and

forming a third semiconductor layer above said second semiconductor layer as a top part of the ridge, said third semiconductor layer being etched at a third etching speed by the first etchant,

15 wherein the second etching speed is higher than the first etching speed and slower than the third etching speed.

14. The method according to claim 13, wherein said second semiconductor layer has a bottom surface located near said first semiconductor layer and top surface located near said third semiconductor layer, and wherein
5 said second semiconductor layer is formed with a composition that causes the second etching speed to be variable and to increase monotonically from the layer's bottom surface to the layer's top surface.

15. The semiconductor device according to claim 14, wherein the second etching speed increases continuously from the bottom surface of said second semiconductor layer to the top surface of said second semiconductor
5 layer.

16. The method according to claim 13, wherein said second semiconductor layer has a bottom surface located near said first semiconductor layer and top surface located near said third semiconductor layer, and wherein
5 said second semiconductor layer is formed with a composition that causes the second etching speed to be variable and to increase in one or more steps from the layer's bottom surface to the layer's top surface.

17. The method according to claim 14, wherein the second semiconductor layer comprises two or more atomic elements, and wherein the stoichiometric ratio of the elements of said second semiconductor layer is
5 sequentially changed to thereby make the second etching speed variable.

18. The method according to claim 13, wherein said first semiconductor layer comprises a composition $\text{Al}_{x_1}\text{Ga}_{1-x_1}\text{As}$ where x_1 is substantially constant, wherein said third semiconductor layer comprises a composition of
5 GaAs, and wherein said second semiconductor layer comprises a composition of $\text{Al}_{x_2}\text{Ga}_{1-x_2}\text{As}$ where x_2 is a variable.

19. The method according to claim 13 further comprising a step of forming an electrode layer above said third semiconductor layer and covering at least the side of said ridge portion in the longitudinal direction,
5 wherein the thickness of said electrode layer is equal to or more than 100 nm.

20. The method according to claim 13 further comprising a step of forming an electrode layer above said third semiconductor layer and covering at least the side of said ridge portion in the longitudinal direction,
5 wherein the thickness of said electrode layer is equal to or more than 150 nm.

21. The method according to claim 13 further comprising a step of forming an electrode layer above said third semiconductor layer and covering at least the

side of said ridge portion in the longitudinal direction,
5 wherein the thickness of said electrode layer is equal to
or more than 200 nm.

22. A semiconductor device having a multiple
layered ridge formed at a first surface of a substrate,
said ridge including:

a base attached to the substrate, an upper face
5 located above the base, and at least a first side face
located between the ridge's upper face and the base;

a first semiconductor layer located closer to the
base than the upper face of the ridge, said first
semiconductor layer having a composition of $\text{Al}_{x1}\text{Ga}_{1-x1}\text{As}$
10 where the stoichiometric parameter $x1$ is substantially
constant;

a second semiconductor layer located above said
first semiconductor layer and below said upper face, said
second semiconductor layer having a composition of
15 $\text{Al}_{x2}\text{Ga}_{1-x2}\text{As}$ where the stoichiometric parameter $x2$ is
variable with a range of values which are less than or
equal to $x1$; and

a third semiconductor layer located above said
second semiconductor layer and below said upper face,
20 said third semiconductor layer having a composition of
 $\text{Al}_{x3}\text{Ga}_{1-x3}\text{As}$ where the stoichiometric parameter $x3$ is
substantially constant and substantially less than or
equal to the lowest value of the stoichiometric parameter
 $x2$; and

25 wherein said second semiconductor layer has a
bottom surface located near the first semiconductor layer
and top surface located near the third semiconductor
layer,

wherein the stoichiometric parameter X2 decreases
30 monotonically from the bottom surface of the second
semiconductor layer to the top surface of the second
semiconductor layer, and

wherein said first side face comprises a forward
mesa surface.

23. The semiconductor device according to claim 22,
wherein said second semiconductor layer has a bottom
surface located near the first semiconductor layer and
top surface located near the third semiconductor layer,
5 and wherein the stoichiometric parameter x2 decreases
monotonically from the layer's bottom surface to the
layer's top surface.

24. The semiconductor device according to claim 23,
wherein the stoichiometric parameter x2 decreases
continuously from the bottom surface of said second
semiconductor layer to the top surface of said second
5 semiconductor layer.

25. The semiconductor device according to claim 22,
wherein said second semiconductor layer has a bottom
surface located near the first semiconductor layer and
top surface located near the third semiconductor layer,
5 and wherein the stoichiometric parameter x2 decreases in
one or more steps from the layer's bottom surface to the
layer's top surface.

26. The semiconductor device according to claim 22,
wherein said first side face comprises a concave surface.

27. The semiconductor device according to claim 22, wherein the stoichiometric parameter x_1 for the first semiconductor layer is in a range of 0.2 to 0.5.

28. The semiconductor device according to claim 22, wherein the stoichiometric parameter x_1 for the first semiconductor layer is in a range of 0.25 to 0.35.

29. The semiconductor device according to claim 22, wherein the stoichiometric parameter x_1 for the first semiconductor layer is in a range of 0.2 to 0.5, and wherein the stoichiometric parameter x_3 for the third
5 semiconductor layer is less than or equal to 0.05.

30. The semiconductor device according to claim 22, wherein the third semiconductor layer comprises GaAs with the stoichiometric parameter x_3 being substantially equal to zero.

31. The semiconductor device according to claim 22 wherein said second semiconductor layer has a thickness in a range of 5 nm to 1000 nm.

32. The semiconductor device according to claim 22 wherein said second semiconductor layer has a thickness in a range of 25 nm to 100 nm.

33. The semiconductor device according to claim 22 wherein said second semiconductor layer has a thickness in a range of 25 nm to 35 nm.

34. The semiconductor device according to claim 32 wherein the thickness of said first semiconductor layer is greater than the thickness of said second semiconductor layer, and wherein the thickness of the
5 third semiconductor layer is greater than the thickness of the second semiconductor layer.

35. The semiconductor device according to claim 22 further comprising an electrode layer disposed above said third semiconductor layer and covering at least the side of said ridge portion in the longitudinal direction,
5 wherein the thickness of said electrode layer is equal to or more than 100 nm.

36. The semiconductor device according to claim 22 further comprising an electrode layer disposed above said third semiconductor layer and covering at least the side of said ridge portion in the longitudinal direction,
5 wherein the thickness of said electrode layer is equal to or more than 150 nm.

37. The semiconductor device according to claim 22 further comprising an electrode layer disposed above said third semiconductor layer and covering at least the side of said ridge portion in the longitudinal direction,
5 wherein the thickness of said electrode layer is equal to or more than 200 nm.

38. A method of manufacturing a semiconductor device having a multiple layered ridge, the ridge having a base attached to a substrate, an upper face located above the base, and at least a first side face located
5 between the ridge's upper face and the base, the method comprising the steps of:

(a) forming a first semiconductor layer located closer to the base than the upper face of the ridge, the first semiconductor layer having a composition of
10 $\text{Al}_{x_1}\text{Ga}_{1-x_1}\text{As}$ where the stoichiometric parameter x_1 is substantially constant;

(b) forming a second semiconductor layer over the first semiconductor layer and located below the upper face, the second semiconductor layer having a bottom
15 surface adjacent to the first semiconductor layer and top surface opposite to the bottom surface, the second semiconductor layer having a composition of $\text{Al}_{x_2}\text{Ga}_{1-x_2}\text{As}$ where the stoichiometric parameter x_2 is variable with a range of values which are less than or equal to x_1 , the
20 second layer being formed such that the stoichiometric parameter x_2 decreases substantially monotonically from the bottom surface of the second semiconductor layer to the top surface of the second semiconductor layer; and

(c) forming a third semiconductor layer over the
25 second semiconductor layer and located below the upper face, the third semiconductor layer having a composition of $\text{Al}_{x_3}\text{Ga}_{1-x_3}\text{As}$ where the stoichiometric parameter x_3 is substantially constant and substantially less than or equal to the lowest value of the stoichiometric parameter
30 x_2 ; and

(d) exposing selected portions of the first, second, and third semiconductor layers to a common

etchant to form the ridge such that at least a portion of
the first side surface of the ridge has a slope of a
35 forward mesa ridge.

39. The method of claim 38, wherein the second
semiconductor layer is formed such that the
stoichiometric parameter x_2 decreases continuously from
the bottom surface of said second semiconductor layer to
5 the top surface of said second semiconductor layer.

40. The method of claim 38, wherein the second
semiconductor layer is formed such that the
stoichiometric parameter x_2 decreases in one or more
steps from the bottom surface of said second
5 semiconductor layer to the top surface of said second
semiconductor layer.

41. The method of claim 38, wherein the first side
face comprises a concave surface.

42. The method of claim 38, wherein the
stoichiometric parameter x_1 for the first semiconductor
layer is in a range of 0.2 to 0.5.

43. The method of claim 38, wherein the
stoichiometric parameter x_1 for the first semiconductor
layer is in a range of 0.25 to 0.35.

44. The method of claim 38, wherein the
stoichiometric parameter x_1 for the first semiconductor
layer is in a range of 0.2 to 0.5, and wherein the
stoichiometric parameter x_3 for the third semiconductor

5 layer is less than or equal to 0.05.

45. The method of claim 38, wherein said second semiconductor layer has a thickness in a range of 5 nm to 1000 nm.

46. The method of claim 38, wherein said second semiconductor layer has a thickness in a range of 25 nm to 100 nm.

47. The method of claim 38, wherein said second semiconductor layer has a thickness in a range of 25 nm to 35 nm.

48. The method of claim 46, wherein the thickness of said first semiconductor layer is greater than the thickness of said second semiconductor layer, and wherein the thickness of the third semiconductor layer is greater
5 than the thickness of the second semiconductor layer.

49. The method according to claim 38, further comprising a step of forming an electrode layer above said third semiconductor layer and covering at least a portion of the first side of said ridge portion in the
5 longitudinal direction, wherein the thickness of said electrode layer is equal to or more than 100 nm.